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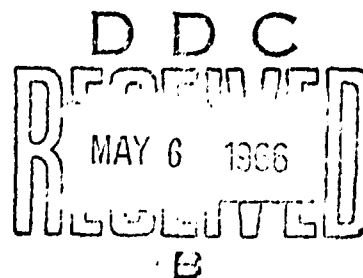DISTRIBUTION UNLIMITED.

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# SPX-A BOOSTER EXPLOSIVE WHICH CAN BE INITIATED BY·SOURCES OF SMALL DIMENSIONS

R. H. STRESAU

R. L. DEGNER

D D C

MAY 6 1966

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## NAVAL ORDNANCE LABORATORY CORONA

CORONA, CALIFORNIA

# NAVAL ORDNANCE LABORATORY CORONA

**E. B. JARMAN, CAPT., USN**
Commanding Officer

**F. S. ATCHISON, Ph. D.**
Technical Director

## ABSTRACT

The objective of the work described was the development of an RDX-base explosive that can be initiated by explosive charges of very small dimensions, such as Mild Detonating Fuse (MDF), but will meet Navy requirements for a booster explosive. By these requirements, an explosive may be no more sensitive than tetryl. Such characteristics may be expected of finely divided RDX desensitized with a waxy substance. RDX of a mean particle size close to 10 microns was prepared by pouring a solution of RDX in hot acetone into chilled water. The finely divided RDX was desensitized with various percentages of calcium stearate by precipitating the latter from a sodium stearate solution (the vehicle of an RDX slurry) with calcium chloride. The Spooner small-scale gap test, which is a poor man's version of the Naval Ordnance Laboratory, White Oak (NOL/WO) small-scale gap test, shows SPX (finely divided RDX coated with 1.5% calcium stearate) to have almost exactly the sensitivity of CH-6, which is, in turn, significantly less sensitive than tetryl. SPX can usually be initiated by means of MDF loaded with one grain per ft PETN and it is reliably initiated by five grains per ft MDF. In contrast, CH-6 cannot be initiated by means of 10 grains per ft MDF. A Varicomp (SVC) series of finely divided RDX/calcium stearate mixtures closely paralleled the NOL/WO Varicomp series of mill-run RDX/calcium stearate in small-scale gap test sensitivity. A microscale gap test was devised in which 5-grain MDF was used as the donor to simulate an intended condition of use. The microscale gap test sensitivities of the SVC series, when plotted against stearate content, showed more scatter than did the small-scale gap test sensitivities.

# FOREWORD

The development work covered in this report was done by the authors in the summer of 1963 as part of Contract N123 (62738)31089A between the Naval Ordnance Laboratory, Corona, California, and the R. Stresau Laboratory, Inc., Spooner, Wisconsin.

The body of the report and the illustrations are substantially as submitted by the authors in fulfillment of contract requirements.

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B. F. HUSTEN
Head, Fuze Department

# CONTENTS

# INTRODUCTION

Recent developments, including that of Mild Detonating Fuse (Ref. 1),[1]
suggest that fuze explosive trains and other high-explosive systems can
be made by using explosive components of much smaller dimensions than
those currently used in ordnance (Ref. 2). Since the total bulk and weight
of many such systems is nearly proportional to that of the explosive com-
ponents used, such smaller components would remove a barrier to mini-
aturizing fuzes and other systems. The miniaturized fuzes, in turn,
could result in improved performance in smaller ordnance by making
more space available for main charge explosives, improved reliability
in larger ordnance by virtue of increased opportunities for redundancy,
and substantial performance gains in ordnance of various types as the
result of the more sophisticated systems which would be possible.

In most cases where smaller components offer advantages, it is nec-
essary to transfer detonation from the small components to the main
charge of a high-explosive weapon. Most of the advantages of the smaller
components would be lost if safety policy prevented their use in direct
communication with the main charge. The safety policy of the Bureau of
Naval Weapons, as now interpreted, precludes the use of explosives more
sensitive than tetryl in such direct communication. Explosives that are
usable in such positions, but can be initiated by means of standard fuze
explosive components, are referred to as "booster explosives." The
booster explosives most commonly used in naval ordnance, tetryl and
CH-6, will detonate quite reliably in rather small size columns, if well
confined, as in MDF. However, the transfer from such small columns
to larger charges is not particularly reliable unless it is accomplished
quite gradually in a tapered lead or by relatively small stepwise increases.

To attain the full advantage of small explosive components, it should
be possible to initiate a booster or relatively large lead directly. On first
consideration, it would seem that a booster explosive that can be initiated
by a smaller source than can tetryl is a contradiction of terms, since such
an explosive would have to be more sensitive than tetryl. If the criterion
of sensitivity were the size of source for threshold initiation, this would
be unarguable. The criteria which have been used to characterize sensi-
tivity in the application of Navy policy have been impact sensitivity tests,

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[1]Mild Detonating Fuse and MDF are trademarks of E. I. du Pont
de Nemours & Company for metal-jacketed detonating cord with linear
explosive densities of one to 20 grains per foot.

such as those with ERL Type 12 tools (Ref. 3), and gap tests, such as
the Naval Ordnance Laboratory, White Oak (NOL/WO) small-scale gap
test (SSGT) (Ref. 4). In such tests, the quantity of explosive exposed to
the experimental stimulus remains nearly constant, while the intensity
of the stimulus is varied. In contrast, initiation by a small source, such
as MDF, involves stimuli of nearly the same intensity as that delivered
by a fuze component of currently used dimensions, but the quantity of
explosive exposed to the stimulus is much reduced. Even without con-
sideration of the mechanisms involved, it is reasonable to expect that
the susceptibilities of various explosives to initiation by such differing
types of impulse should be something other than direct. There is no
reason to expect that an explosive that can be reliably initiated by means
of smaller MDF than can tetryl would be automatically more sensitive
than tetryl in a gap or impact test.

The experiments described herein were directed toward the develop-
ment of an RDX-base explosive that, when loaded into explosive compo-
nents of standard dimensions (Ref. 2), can be reliably initiated by means
of MDF (five grains of RDX per ft or less), but which is less sensitive
than tetryl according to impact or gap tests. Because of the high cost
of an ERL impact machine and the difficulties of establishing the validity
of impact data obtained with a machine of original design, a gap test was
used to characterize the sensitivities of explosives prepared in this pro-
gram. The general agreement between gap and impact sensitivities (Ref. 5)
leads to the expectation that impact sensitivities of the new explosives
developed in this program and the standard explosives tested would assume
the same general order as their gap-test sensitivities.

## QUALITATIVE THEORETICAL CONSIDERATIONS

Detonation has been described as a reactive shock. A more detailed
description includes a nonreactive shock followed by a reaction zone of
finite thickness. In a stable detonation, the inherent losses associated
with shock waves are exactly compensated by the chemical energy liber-
ated by the reaction.

Stable detonation, where the advancing shock front is a plane surface,
so that only movement perpendicular to the shock front need be considered,
is referred to as "ideal detonation." Conditions at the end of the reaction
zone (usually referred to as the "Chapman-Jouguet point"), as well as the
rate of propagation of an ideal detonation, are determined by the density
and available chemical energy of the unreacted explosive and the equation
of state of the reaction products.

In a "nonideal" detonation, movement in directions other than that of
propagation have significant effects. The two common "naturally occurring"

situations that result in nonideal detonation are found (1) in a charge so small that the effects of expansion at boundaries are transmitted to the Chapman-Jouguet point at the charge axis, and (2) in the expanding detonation in a larger charge which results when it is initiated by a smaller charge.

Eyring and his associates (Ref. 6) showed that the radial movement in cylindrical charges results in curvature of the detonation front and they related the conditions and stability of such detonation to the ratio of the reaction zone length of the explosive to the radius of this curvature. This relationship of detonation conditions and stability to front curvature, quite obviously also applies (though transiently) to the expanding wave that results when a large charge is initiated by means of a smaller charge.

In a detonation, as in any shock, the pressure, density, temperature, particle velocity, and propagation velocity are so interdependent that, in any given medium, the values of each can be determined if one is given. In applying their curved front theory to predict nonideal detonation conditions in cylindrical columns of explosive, Eyring and his associates characterized the strength of detonation in terms of propagation velocity, facilitating direct comparison of theoretical predictions with the largest bulk of experimental data. In Ref. 7, it was suggested that the growth of detonation waves from sources of small dimensions can be traced more easily in a system of coordinates in which vigor of shock or detonation waves from sources of small dimensions is characterized in terms of pressure. The general approach that had been used by Eyring and his associates was to construct a "failure diagram" for expanding spherical waves in coordinates of pressure and the ratio of reaction zone length to radius of front curvature.

In Figure 1, which is a copy of the failure diagram with a few additions, the curves $P_iN_1O$ and $P_iN_2O$ represent equilibrium detonation conditions for expanding spherical detonation waves in two explosives with the same hydrodynamic-thermodynamic conditions (defined by the pressure, $P_i$) and the reaction zone length, $a_i$, for ideal detonation but differing as to the pressure dependence of the reaction rate. $P_iN_1$ and $P_iN_2$ are stable equilibrium conditions, which are approached by all spherical detonations that are not failing. $N_1O$ and $N_2O$ are critical conditions above and to the left of which detonation may be expected to grow to the stable conditions and below which it may be expected to fail. To the right of $N_1$ and $N_2$, the term "detonation" loses its meaning, but the curves $N_1M$ and $N_2M$ define conditions for which the energy lost by the spherically expanding shock wave is exactly compensated by that liberated by the reaction of the explosive. If, when a spherically expanding shock wave is induced in an explosive, conditions are given by a point above and to the left of $ON_2M$ or $ON_1M$ (whichever is applicable to the particular explosive), the reaction will grow to a high-order detonation. If conditions are represented by a point below and to the right of this curve, the reaction will fail.
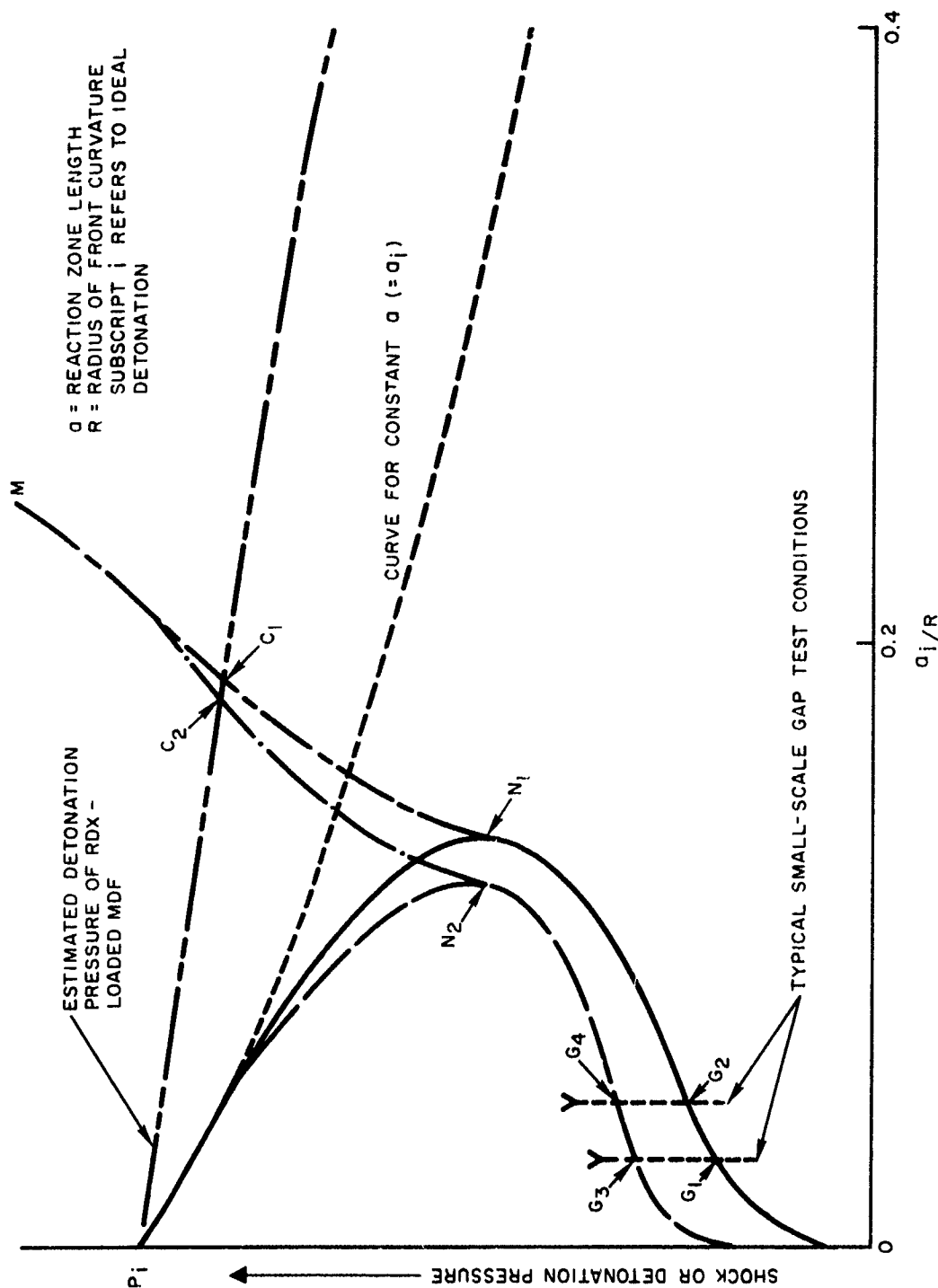
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FIGURE 1. Failure Diagram for Expanding Spherical Detonation Waves, Including Typical Experimental Threshold Initiation Conditions

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In addition to the failure diagram, Figure 1 includes a curve representing the estimated detonation pressure dependence of a lead-encased charge (such as MDF), loaded with a material of constant $P_i$ and $a_i$ (such as RDX at a constant state of aggregation), and a representation of typical small-scale gap test conditions.

It may be noted that, since the abscissae of Figure 1 are ratios of reaction zone length to radius of front curvature, and since the radius of front curvature must be nearly proportional to that of a small column such as MDF, which is used to induce a shock wave in the explosive, the critical size ($C_1$ or $C_2$) of the small column for threshold initiation should be directly proportional to the reaction zone length, a, of the explosive that is being initiated. On the other hand, the effect of the pressure dependence of reaction rate ($C_1$ versus $C_2$) is quite small. In contrast, it may be noted that in a typical gap test, the effect of changes in the pressure dependence of reaction rate ($G_1$ versus $G_3$ or $G_2$ versus $G_4$) is greater than that of the ideal reaction zone length ($G_1$ versus $G_2$ or $G_3$ versus $G_4$). It may be implied from Figure 1 that the critical dimension of a small source for threshold initiation is directly proportional to the reaction zone length and only slightly affected by the pressure dependence of the reaction rate, while gap test sensitivity is more affected by the pressure dependence of reaction rate than by the reaction zone length in ideal detonation.

E/ring and his associates proposed that the reaction that occurs between the shock front and the Chapman-Jouguet point in a granular explosive is a deflagration at the surfaces of the grains. This "surface-burning theory," which is supported by a wide variety of experimental data (Refs. 8, 9, 10, and 11), implies that reaction zone lengths should be nearly proportional to particle size. It follows that the critical source size for initiation of an explosive should be nearly proportional to its particle size.

The fact that the most effective desensitizers for RDX are waxy materials may, in terms of the experimentally verified "hot spot" theory of initiation published by Bowden and Yoffe (Ref. 12), which is mutually supporting with the E/ring surface-burning model of detonation, be interpreted as an indication that the lubricating properties of these materials inhibit the localized heating at grain boundaries. In the terms of Figure 1, this lubrication might be expected to have more effect upon the pressure dependence of the reaction zone rate than upon the ideal reaction zone length. It might, then, be expected that waxy desensitizers should have more effect upon gap or impact sensitivity than upon susceptibility to initiation by small high-intensity sources.

The foregoing suggests that RDX of fine particle size should be more susceptible to initiation by sources of small dimensions, and that this property should not be greatly affected by desensitization with waxy substances, such as stearates. As the experiments described later in this report have shown, this appears to be correct.

# EXPLOSIVES

## General

All explosives used in the experiments described herein were standard military explosives, presumed to have been made in accordance with applicable military specifications, or were modifications of such materials prepared at the Stresau Laboratory.

## Standard Military Explosives

All the standard military explosives used were supplied by the Naval Ordnance Laboratory, White Oak, Maryland. The numbers given are NOL/WO designations for storage lots.

RDX X334. This is also labeled "Holston" RDX, which would indicate that it is made by the Bachman process at the Holston River Ordnance Works and in accordance with Ref. 13. It is Type B RDX, containing about 10% HMX. An approximate sieve analysis is given in Table 1.

TABLE 1. Approximate Sieve Analysis
of RDX X334

| U. S. Standard Sieve | | Percentages |
|---|---|---|
| Through | On | |
| | 40 | 0 |
| 40 | 60 | 2 |
| 60 | 80 | 18 |
| 80 | 100 | 26 |
| 100 | 150 | 27 |
| 150 | 270 | 10 |
| 270 | | 17 |

Ch-6, X-391, Z-417. The specification for CH-6 is given in Ref. 14. It is understood, however, that most CH-6 has been made with waivers of some parts of this specification.

Tetryl. Presumed to be in accordance with Ref. 15. Identified on bottle as "yellow tetryl." Although no sieve analysis was made, an appreciable fraction was coarse enough to be held on a No. 30 U. S. Standard sieve.

## Preparation of Fine Particle RDX by Precipitation

To prepare RDX of fine particle size, the RDX was dissolved in boiling acetone and the solution poured into chilled distilled water while stirring the water vigorously. The usual proportion was 8.5 grams of RDX to 100 cm$^3$ of acetone (about 55% saturation). The quantity of water used was twice (in later preparations, three times) that of acetone. Several such preparations were made, using various types of RDX and variations in detailed procedure. Of these, only one was used in experiments discussed herein:

> RDX XF-2. Made by the process described above from RDX X334. The particles in this precipitation (Figure 2) range from 2 to 20 microns in maximum dimension, with the average close to 10 microns.

The particle size distribution of RDX XF-2 is quite typical of that obtained by this process.



FIGURE 2. Photomicrograph of RDX
XF-2 Particles (X 750)

## Coating With Calcium Stearate To Produce SPX

The process used to coat the finely precipitated RDX was adapted from
that used in the manufacture of CH-6 (Ref. 14) and the NOL/WO Varicomp
(Ref. 16) mixtures. After washing to remove the acetone and after re-
moving excess moisture by either decanting or filtering but without drying,
a 100-gram batch of the precipitated RDX was added to a solution of so-
dium stearate in distilled water and stirred to form a slurry (a small
amount of oil-soluble red dye had been added to the stearate solution).
While continuing to stir, a distilled water solution of calcium chloride
was added gradually, precipitating the calcium stearate and leaving a
sodium chloride solution, which was removed by washing on a filter.
(The oil-soluble dye, of course, followed the stearate and colored the
resulting product pink. The uniformity of the color is visible evidence
of the uniformity of the coating.) After filtering, the material was dried
in an aluminum pan at about 80°C. Three SPXs (SPooner eXplosives)
have been made:

> SPX-1. 100 grams of RDX dissolved in 40 fluid oz of hot acetone
> was poured into 80 fluid oz of distilled water. Acetone concentra-
> tion was reduced by repeatedly adding distilled water, allowing to
> settle, and decanting supernatant liquid. Three grams of sodium
> stearate in 32 fluid oz of water was added and the mixture stirred
> while adding 2 grams of calcium chloride. Settling, decanting, and
> adding of water was repeated for several cycles, after which mate-
> rial was dried. Since only 70 grams was recovered, and time dis-
> tribution of losses is not known, stearate content may be anything
> from slightly less than 3% to a bit over 4%.

> SPX-2. Process is similar to that for SPX-1, but 1.5 grams of so-
> dium stearate and 1 gram of calcium chloride were used with an
> original 100 grams of RDX. Recovery was 80-85 grams.

> SPX-2a. Proportions are the same as for SPX-2, but a double-size
> batch was made   Precipitate and final product washed on filter
> rather than by decanting. Yields obtained using filter washing
> were about 90%.

## SVC Series for Varicomp Evaluations of Explosive Systems

In the determination of the reliability of detonation transfer between
small charges and SPX, the same difficulties are encountered that led
to the development of the Varicomp method for such determinations with
"standard" size explosive components. To apply the Varicomp technique
to small-charge SPX transfers, a series of explosives similar to SPX,
except that larger proportions of stearate were used, was prepared.

These mixtures are designated SVC, which is followed by a number indicating the number of parts of sodium stearate used per 100 parts of RDX. The other materials prepared at the Stresau laboratory have been included in Table 2. SPX-12a was made because SPX-12 was

TABLE 2. The SVC Series for Varicomp Methods

| SVC No. | Other Designation | Percentage Calcium Stearate[a] |
|---------|-------------------|-------------------------------|
| SVC-0 | XF-2 | 0 |
| SVC-1.5 | SPX-2 & SPX-2a | 1.47 |
| SVC-3 | SPX-1 | 2.88 |
| SVC-6 | | 5.62 |
| SVC-12 & SVC-12a | | 10.6 |
| SVC-24 | | 19.1 |

[a]Assuming 100% yields.

somewhat lighter in color and somewhat more sensitive than had been anticipated, indicating that it may have contained somewhat less stearate than intended. SVC-12 was retained as a useful member of the SVC series.

## EXPERIMENTAL ARRANGEMENTS AND PROCEDURE

### General

The explosives prepared in the course of the work described herein were compared with standard military explosives by means of the Spooner small-scale gap test (SSSGT)—a poor man's version of the small-scale gap test (SSGT) standardized by Ayres (Ref. 4) at NOL/WO—as to their susceptibility to initiation by means of Mild Detonating Fuse. In addition, to simulate an application more closely than does the SSSGT, the "micro-scale gap test" (MSGT) was devised for calibration of the SVC series.

### The Bruceton Procedure

The so-called Bruceton test procedure was used in all tests reported herein. In this procedure, the first trial of a test is performed at one of a series of preestablished sets of conditions or steps. If a detonation results, the next trial is performed at the adjacent condition or step in the direction less conducive to detonation. If it misfires, the next trial

is performed at the adjacent step in the direction of increasing detonation transfer probability. The test is continued in this manner, the conditions of each trial being determined by the results of the previous trial. Figure 3 is a typical test data sheet.

Information obtained in a Bruceton test may be analyzed to obtain estimates of the mean (the condition at which 50% will detonate) and standard deviation of the test variable and of the errors of these estimates. The validity of these estimates rests on the assumption that the probability of detonation is normally distributed with respect to the test variable or the function thereof used in establishing the series of steps. Experience indicates that for gap tests, as for many other sensitivity tests, steps so chosen that the logarithms of the gap lengths form an arithmetic progression lend as much validity to this assumption as is practically possible. The "gap decibang" (DBg) series proposed by Ayres (Ref. 4) and used in the SSGT is such a series, for which the transformation function is

$$X = -10 \log G$$

where X is the initiation intensity in DBg and G is the gap in inches. For the SSSGT, the same series of gap lengths was adopted, but to avoid ambiguities resulting from its differences in detailed test conditions from the SSGT, the sensitivity gap decibang unit is abbreviated DBgs rather than DBg.

For the MDF Initiation Susceptibility Test, the steps used were available sizes of MDF—1, 2, 5, 10, and 20 grains per ft. These steps, of course, are not uniform with respect to any function. Even if they were, they are too large to give any reasonable estimate of the standard deviation. In these experiments, the Bruceton procedure was used merely as a convenient test plan, and the "means" should be considered merely as indices of this susceptibility rather than estimates of the size of MDF that would result in 50% detonation of the acceptor.

Uniform step sizes were used for convenience in the MSGT. Although logarithmic steps would be more realistic, the linearly distributed steps result in more conservative estimates of reliability.

Loading Conditions

With one or two exceptions, all the explosives used in these experiments were loaded at 10,000 lb per sq in. Increments were measured volumetrically, following the general rule that the length-to-diameter ratio of an increment should not exceed 1. Because of the low bulk density of the fine particle explosives prepared at the Stresau laboratory, increment lengths of these materials were usually much shorter than this.

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## BRUCETON DATA SHEET NO. _____

Type of Test __*SSSGT*_____ Item _____ Dwg No. _____

Variable __*WAX GAP*_____ Step Size __*¼ DBgs*_____

Criterion of Fire __*DENT*_____

Bridgewire Material _____ Dia. _____

**Explosives**

Flash Charge _____ Base Charge _____ Donor __*B100 MDF*__ Acc. *SPX-2 (4)*

**Charge Dia. or Other Size**

Flash Charge _____ Base Charge _____ Donor *1½ IN. long* Acc. *13/64 IN.*

**Loading Pressure or Density**

Flash Charge _____ Base Charge _____ Donor _____ Acc. *10K PSI*

| DBgs | WAX GAP | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7½ | 0.178 | | | | | | | | | | X | | X | | X | | | | | | |
| 7¼ | 0.189 | | | | | X | | | | O | | O | | O | | X | | X | | | |
| 7 | 0.200 | | X | | O | | X | | O | | | | | | | | X | | O | | O |
| 6¾ | 0.212 | O | | O | | | | O | | | | | | | | | | | | O | |

FIGURE 3.   Typical Bruceton Data Sheet

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# FIRING TEST ARRANGEMENTS

## SSSGT

The setup shown in Figure 4 was used for the SSSGT. A 1 in. long steel cylinder, with 1 in. O.D. and 13/64 in. I.D., was loaded with the acceptor explosive. The donor explosive used in all the SSSGT tests was a 1-1/2 in. length of B100 LJDF (lead-jacketed detonating fuse containing 100 grains of RDX per ft). The length of donor was fitted flush in a wooden block and paraffin wax spacers ( in 1/4 DBg step sizes) were used as the variable. The parts of the firing test arrangement were aligned by fitting them in a paper tube as shown in the diagram. Initiation of the donor was accomplished with a blasting cap, which was butted head-on to the MDF with spaghetti tubing.

## MDF Initiation Susceptibility

For this test, the explosive being tested was loaded in a steel cylinder (Figure 5), as in the SSSGT tests. The donor explosive was various sizes of Mild Detonating Fuse. Holes of the proper size were drilled in steel blocks and the donor length of MDF was fitted flush with the surface of the block. A blasting cap, butted head-on to the length of MDF donor, served to initiate it.

## MSGT

A diagram of the firing test arrangement for these tests is shown in Figure 6. The explosive being tested was loaded in 3/8 in. steel cases, 1/2 in. long, with a 0.132 in. I.D. The correct number of Mylar spacers (0.002 in. steps) and the loaded case were then fitted into the wooden location block. A 1 in. length of A5 MDF (5 grains of PETN per ft) was then inserted in the wooden block and cut off flush with the surface of the wooden block when it was seated on the Mylar spacers. Initiation of the donor MDF was accomplished with a blasting cap, which was taped to the wooden block in a horizontal position with its side butted against the MDF.

# RESULTS AND DISCUSSION

## General

Experimental results are given in Table 3, which also includes some SSGT data, supplied by Ayres (Ref. 17), for comparison of SSSGT and SSGT data.
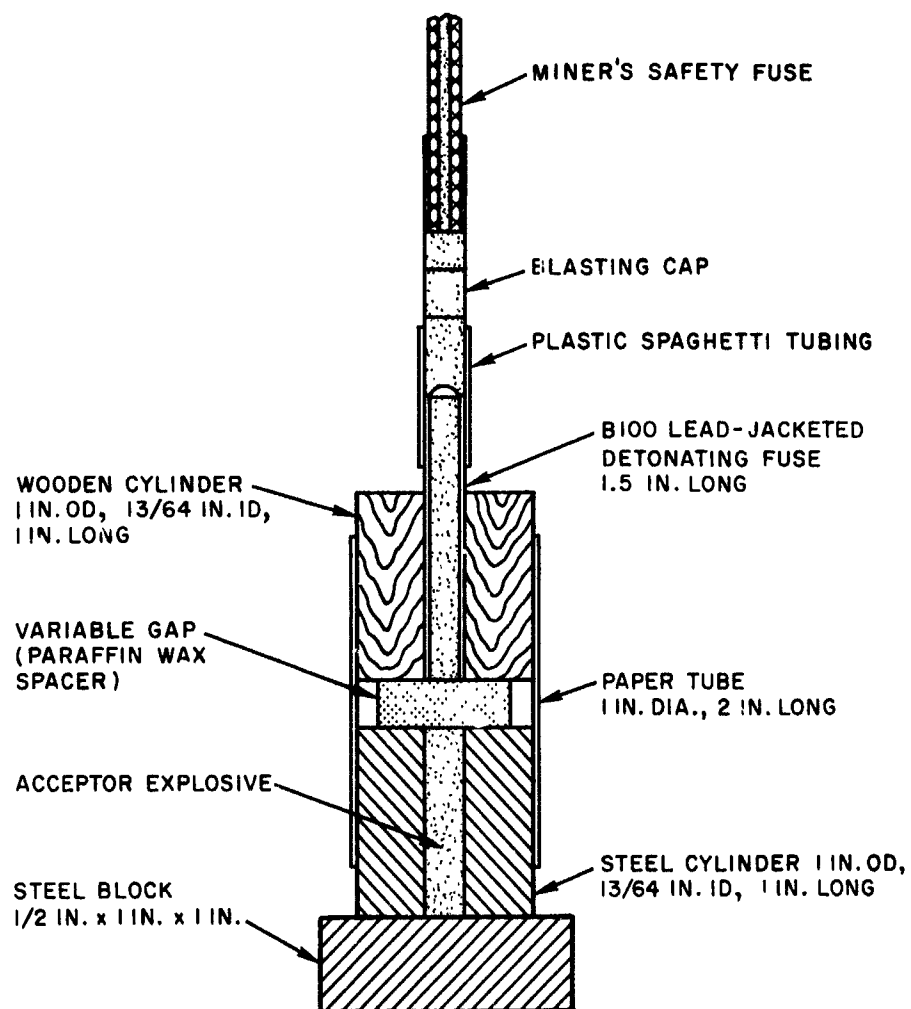
FIGURE 4. Diagram of SSSGT Setup
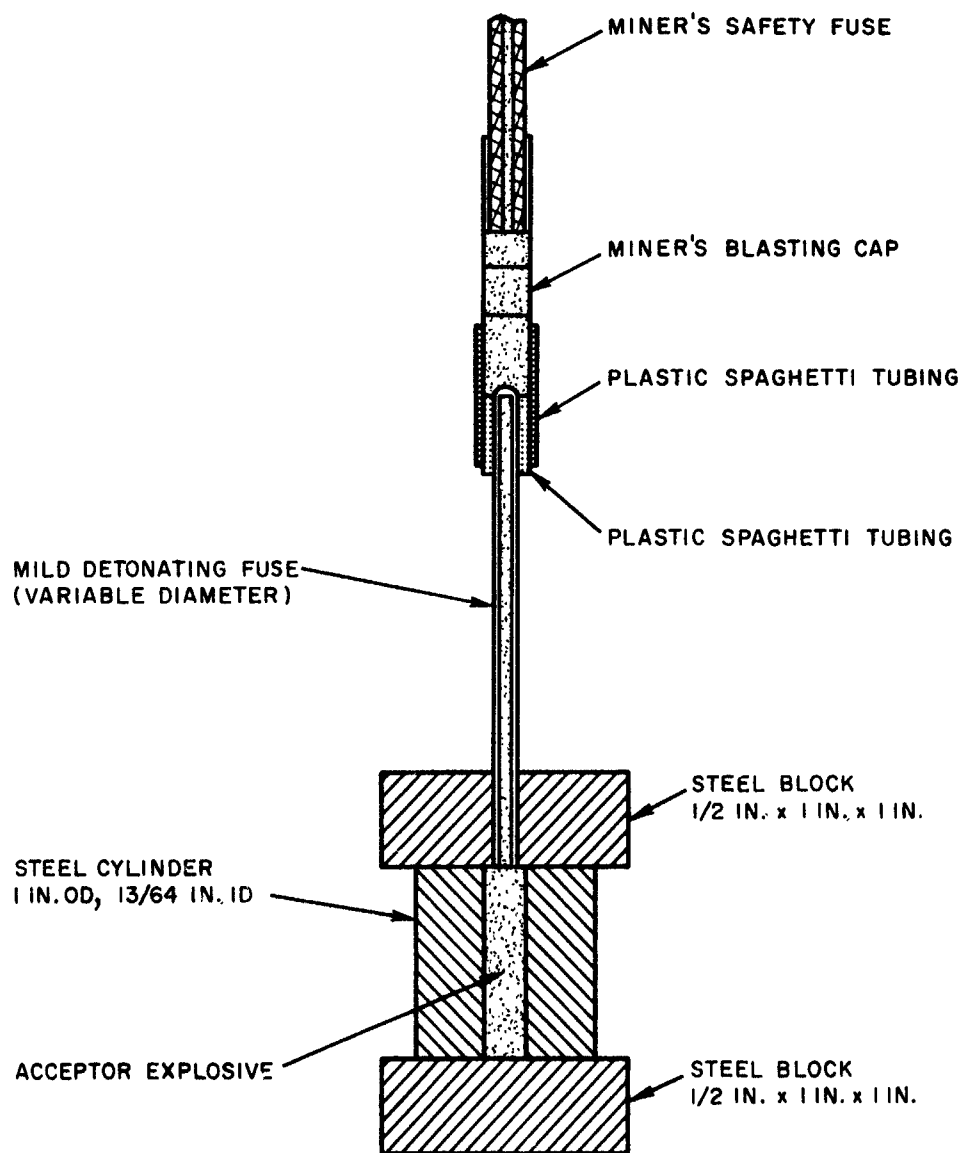
FIGURE 5. Diagram of MDF Initiation Susceptibility
Test Setup

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MINER'S SAFETY FUSE

BLASTING CAP

A5 MDF (5 GRAINS PETN PER FT) I IN. LONG

WOODEN CYLINDER I IN. OD, I 1/2 IN. LONG

VARIABLE GAP (0.002 IN. MYLAR SPACERS)

3/8 IN. SEAMLESS STEEL TUBING 0.132 IN. ID, 1/2 IN. LONG

ACCEPTOR EXPLOSIVE

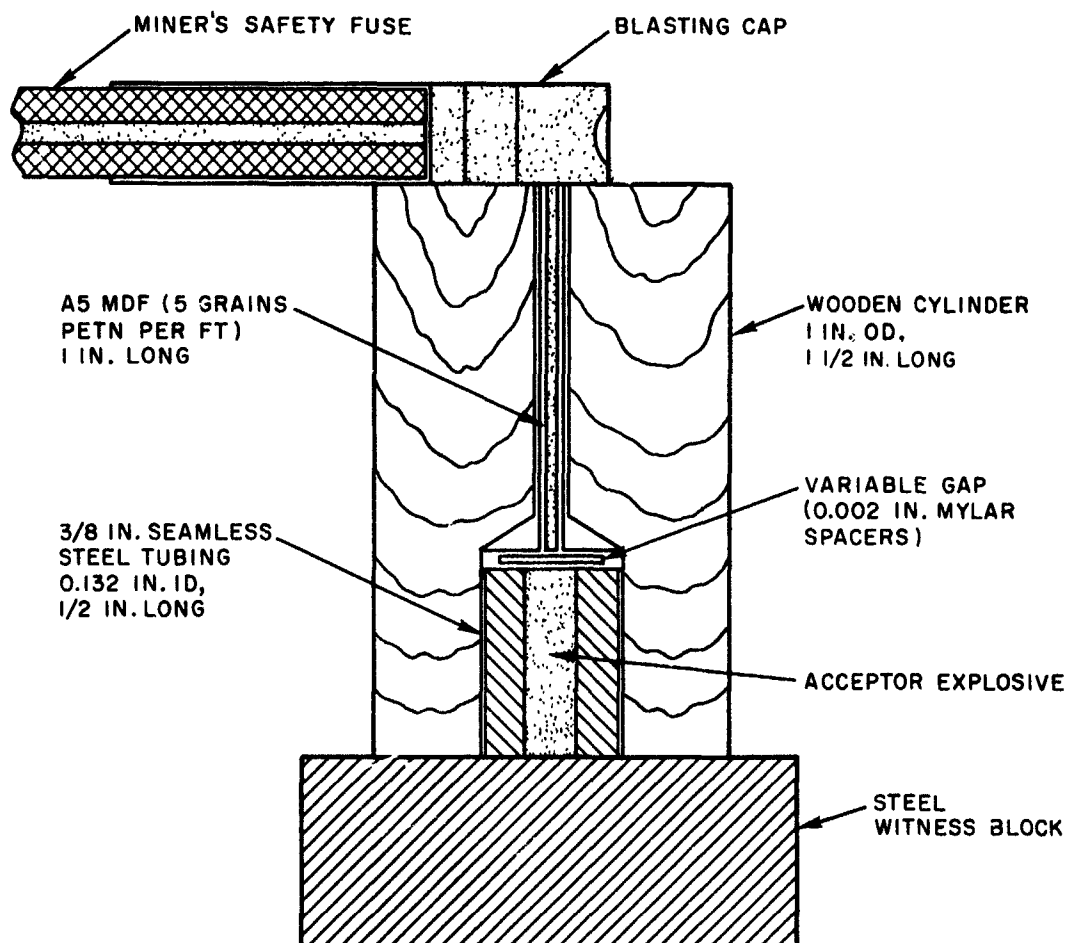STEEL WITNESS BLOCK

FIGURE 6. Diagram of MSGT Firing Test Arrangement

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TABLE 3. Experimental Results

| Explosive | Density (gm/cm$^3$) | Loading Pressure (lb/in.$^2$) | NOL/WO SSGT Mean (DBg) | SSSGT[a] Mean (DBgs) | SSSGT[a] Std. Dev. (DBgs) | MDF Mean[b] Sensitivity (Grains PETN per ft) | MSGT Mean[b] (in. of Mylar Barrier) |
|---|---|---|---|---|---|---|---|
| RDX X334 RDX X189 | 1.62 | 10,000 10,000 | 3.28 | 5.13 | 0.19 | 4.1 | 0.001 |
| RDX XF-2 | 1.51 | 10,000 | | 5.93 | 0.25 | 1.2 | 0.020 |
| Tetryl Tetryl X102 | 1.58 | 10,000 10,000 | 3.63 | 6.30 | 0.18 | 5.5 | |
| SPX-2 SPX-2 | 1.51 | 10,000 5,000 | | 6.75 | 0.30 | 0.7 | 0.019[a] 0.020[c] |
| CH-6 CH-6 X255 CH-6 X267 | 1.60 | 10,000 10,000 10,000 | 3.58 4.54 | 6.80 | 0.15 | 15.0 | |
| SPX-2 (a) SPX-2 (a) | 1.47 1.52 | 5,000 10,000 | | 6.90 7.13 | 0.13 0.28 | 0.5 0.7 | 0.019 0.021 |
| SPX-1 | 1.58 | 10,000 | | 7.55 | 0.15 | 2.0 | 0.012 |
| SVC-6 | 1.52 | 10,000 | | 7.80 | 0.10 | 1.7 | 0.010 |
| SVC-12 | 1.51 | 10,300 | | 7.88 | 0.25 | 3.5 | 0.014 |
| SVC-12 (a) | 1.42 | 10,000 | | 8.29 | 0.13 | 2.9 | 0.011 |
| SVC-24 | 1.53 | 10,000 | | 9.63 | 0.25 | 15.0 | <000 |

[a] Based on 20-shot Bruceton tests.
[b] Based on 10-shot Bruceton tests.
[c] Based on 40-shot Bruceton tests.

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## Comparison Between SSSGT and SSGT

Unfortunately, none of the explosives at hand were of lots for which SSGT data are available. From data for RDX, tetryl, and CH-6 given in Table 3, it may be seen that SSSGT values in DBgs units are two or three units higher than SSGT values in DBg. The tests agree regarding the ordering of RDX, tetryl, and CH-6. The scatter of the differences between values for the same explosives is of the same order as the scatter of SSGT values for various lots of the same explosive. The fact that the lowest standard deviation in the group of explosives tested is 0.10 DBgs, although in almost any similar group of SSGT data one or a few deviations as small as 0.05 DBg is observed, may be taken as evidence that the inherent variability of the SSSGT may be somewhat greater than that of the SSGT. This larger variability is to be expected in view of the many refinements of the SSGT, which have been left out of the SSSGT.

## Effect of Particle Size on Gap Sensitivity

Previous experience with explosives in the size range from 20 to 100 mesh indicated that gap sensitivity increases with decreasing particle size (Ref. 18 and 19). In the present experiments, however, the RDX XF-2, with a mean particle size on the order of 10 microns, turned out to be significantly less sensitive than RDX X334, with a mean particle size well over 100 microns. Ayres (Ref. 17) mentions similar observations with the SSGT. Note that this trend is sufficient to counteract the effects of the density differential. It may be suggested that gap sensitivity is maximized at some "optimum" particle size. An interesting practical application of this trend lies in the possibility that RDX with a still finer particle size may, without additive, comply with the Navy definition of a booster explosive as an explosive less sensitive than standard tetryl.

## Effect of Particle Size on MDF Initiation
## Susceptibility

Note the substantially greater susceptibility of RDX XF-2, as compared with RDX X334, and the still greater contrast in this respect between SPX-2 and CH-6. The effect is essentially as predicted in the discussion of qualitative theoretical considerations above.

## Effect of Calcium Stearate on SSSGT
## of Finely Divided RDX

As may be seen in Figure 7, SSSGT sensitivity of SVC explosives closely parallels SSGT sensitivity of NOL Varicomp explosives. Unfortunately, these data are not particularly pertinent to explosive systems for which SPX was devised.
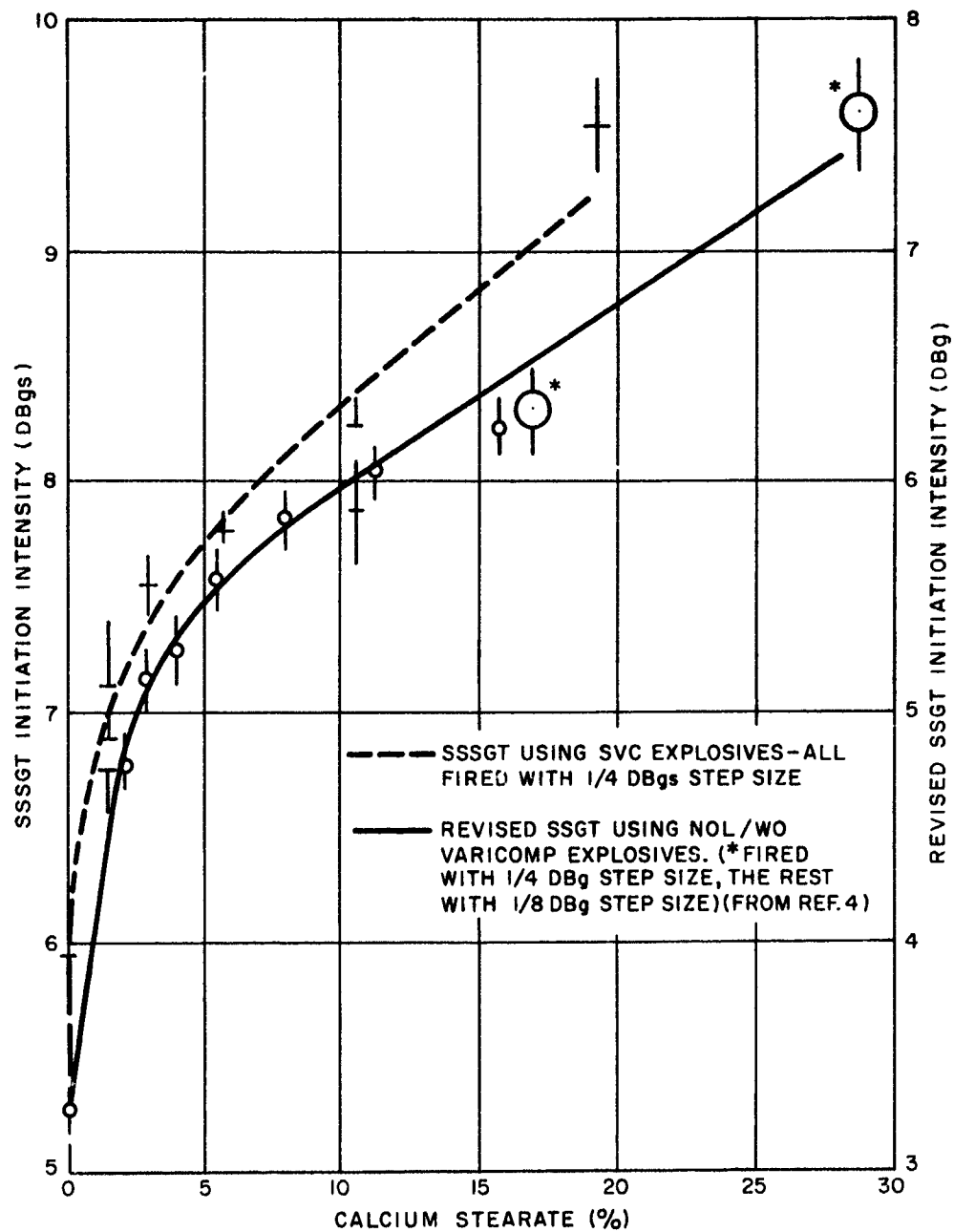
FIGURE 7. Sensitivity of Mixtures of RDX and Calcium Stearate

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## Effect of Calcium Stearate on MDF Initiation Susceptibility

In Figure 8, note that for the finely divided SVC explosives the effect of calcium stearate, in concentrations up to 10%, is appreciably less than that of particle size. This is as would be predicted from the construction of Figure 1.

## MSGT Calibration of SVC Explosives

In Figures 9 and 10, it is seen that although the general trend of MSGT sensitivity as related to stearate concentration is in the right direction and in reasonable agreement with SSSGT sensitivity, the scatter is much too great for Varicomp techniques (Ref. 16) using series of explosives of graded sensitivity. For a particular application (Ref. 20), it was found possible to use one of the single Varicomp explosive techniques (Ref. 16). The scatter of the MSGT data (as well as that of the MDF initiation suscep- tibility data, Figure 8) is possibly attributable to variations in particle size, particle size distribution, and uniformity of stearate coating. The rela- tively crude preparation techniques that have been used up to now are apparently insufficient for the preparation of an adequate series of Vari- comp explosives for use in the evaluation of explosive systems with micro- miniaturized explosive components. However, the control of properties, which has been attained with such rudimentary techniques, gives promise that, with a little refinement to improve control, a satisfactory series can be prepared. An interesting possibility would be a series in which particle size rather than composition is the variable used to control initia- tion susceptibility. Such a series would, of course, have to be calibrated for various sizes of source, and might reverse its slope for greatly dif- ferent sizes.

## Loading of SPX

The very low bulk densities and poor flow properties of finely divided explosives such as SPX are not conducive to efficient production loading by present techniques. A possibility, the investigation of which has been assigned to the Stresau laboratory as a future task, is that of "graining" the material into larger grains, each consisting of many particles of SPX. Of course graining may affect the small charge initiation susceptibility for which this material was developed. This would probably depend upon the graining technique used. It is believed that a material with much improved loading properties can be developed, one that will retain the desirable properties of SPX. Meanwhile, in many applications the advan- tages of miniaturization of fuzes and other explosive systems should out- weigh a certain inconvenience in loading.
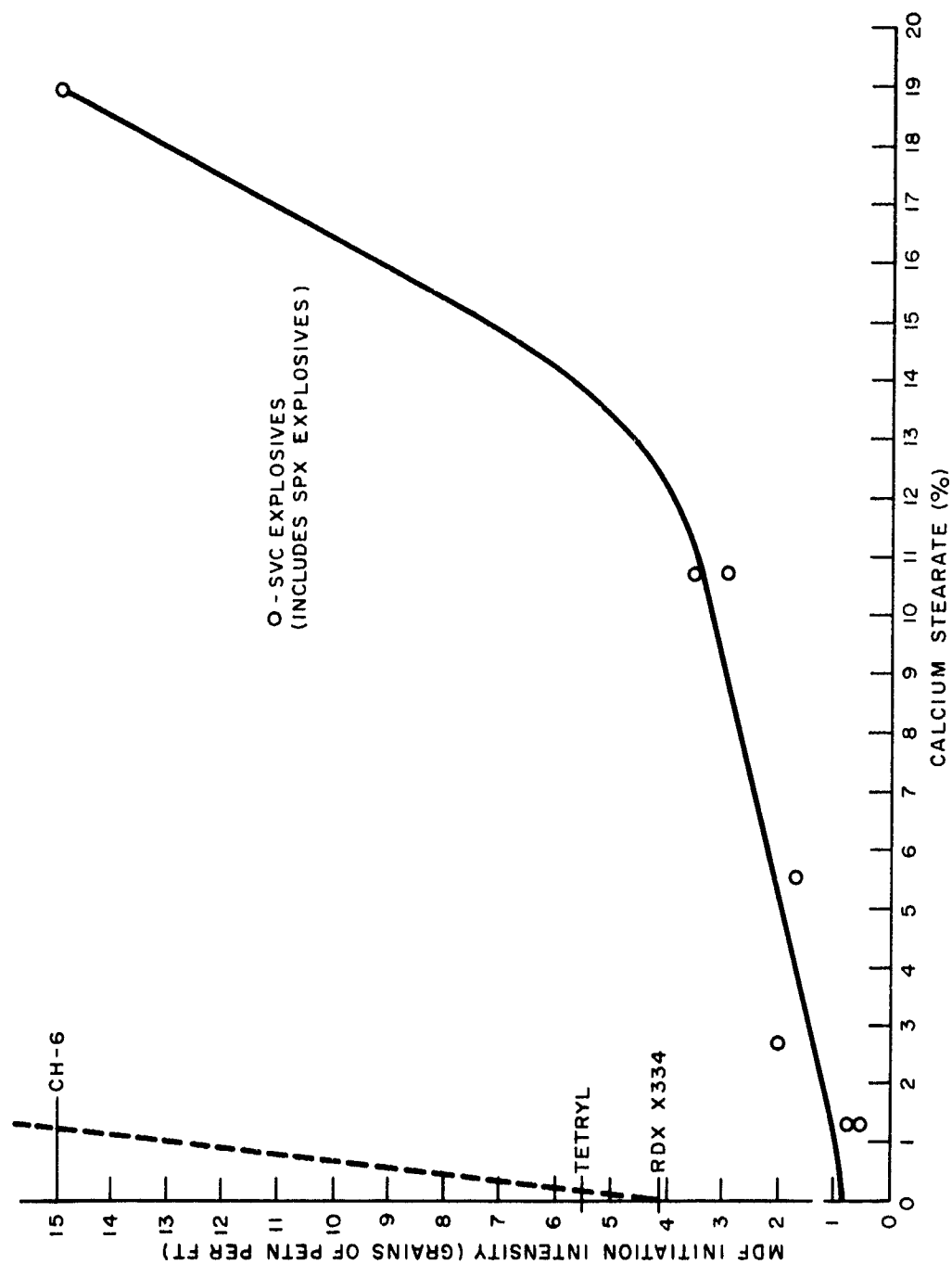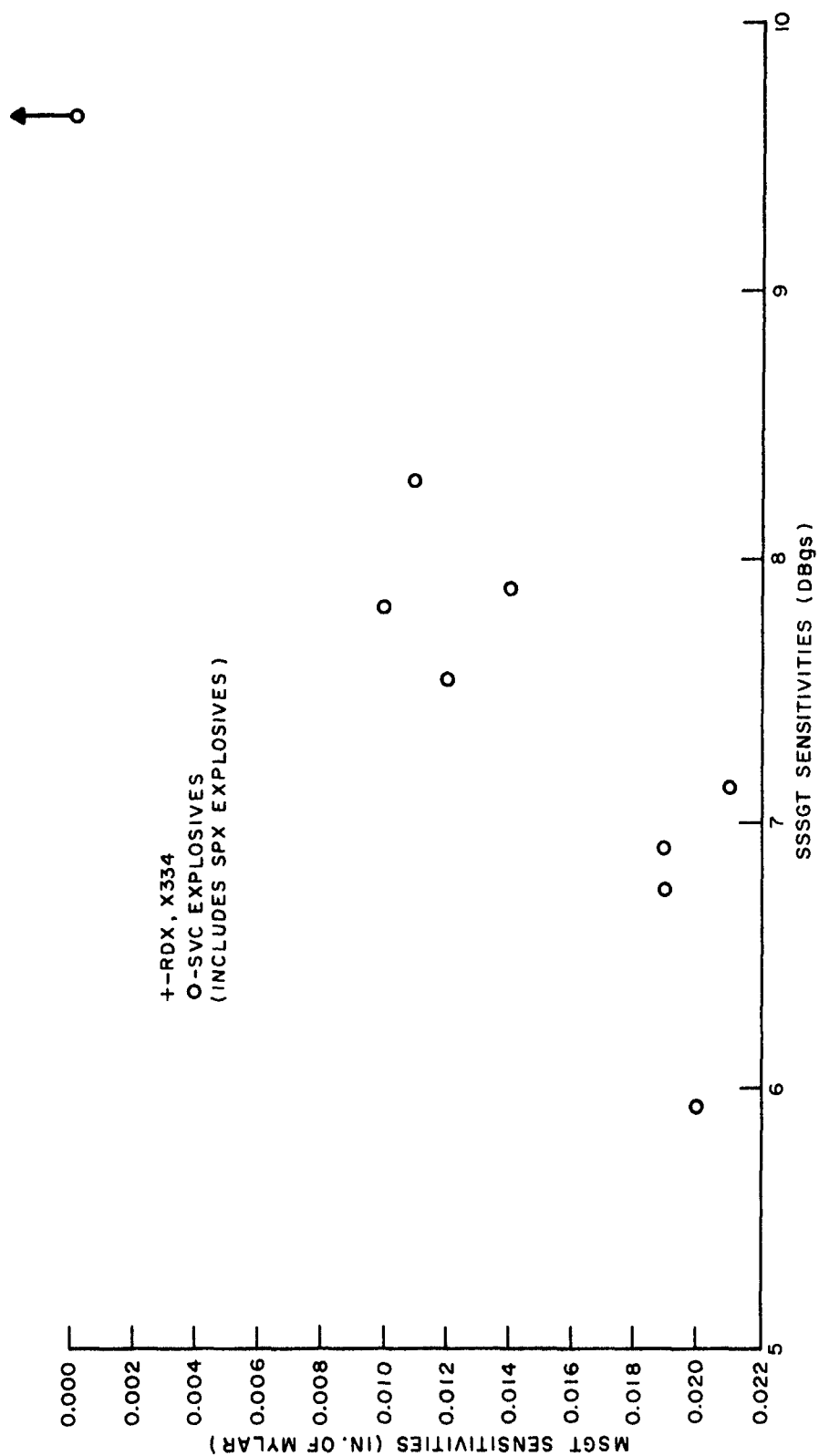
19

FIGURE 8. MDF Initiation Susceptibility

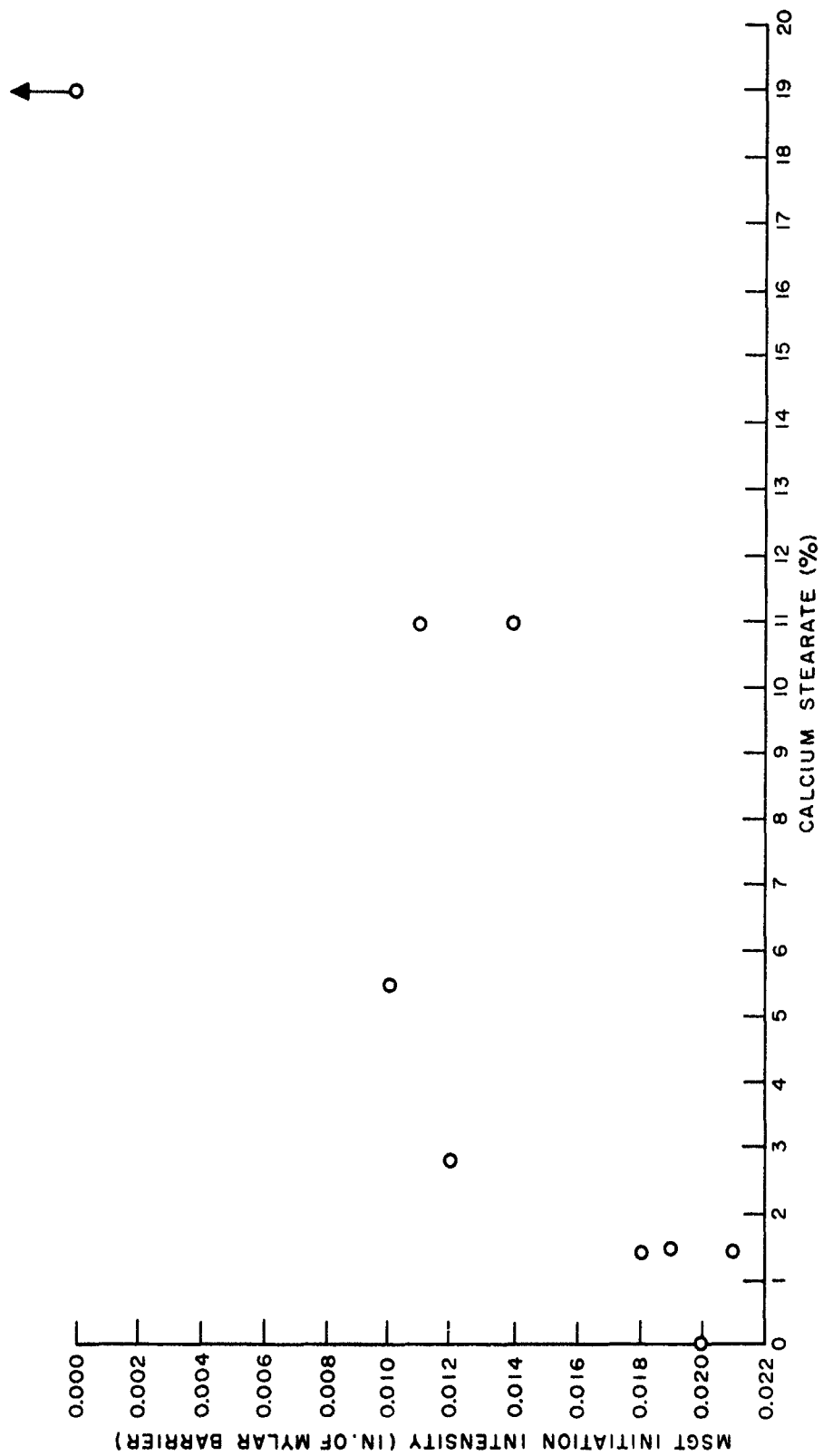FIGURE 9. MSGT Sensitivities Plotted as a Function of SSSGT Sensitivities

FIGURE 10.  MSGT Sensitivity of SVC Explosives (Includes SPX Explosives)

## Output of SPX

The relatively low loading densities obtained when SPX is loaded at 10,000 lb per sq in. (see Table 3) might lead to the impression that the output would be correspondingly decreased. Quite to the contrary, measurements of the dents produced in the witness plates of the SSSGT indicate that SPX-2, at a density of 1.47 $gm/cm^3$ has at least as great an output as RDX X334 at 1.62 $gm/cm^3$ and appreciably greater output than CH-6 at 1.60 $gm/cm^3$. In addition, "low orders," which were the usual type of misfire in the tests of CH-6 and were occasionally observed with tetryl, were completely absent with SPX and SVC explosives, which either detonated "high order" or failed completely.

## CONCLUSION AND RECOMMENDATION

It may be concluded that SPX-2 can be reliably initiated by means of MDF and other explosive components with charge diameters on the order of 1/32 in. Although further development is needed in the areas of improved loadability and refinement of explosive system evaluation techniques, it is possible to recommend that serious consideration be given the advantages inherent in systems with explosive components of such small dimensions.

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| Booster Explosive | | | | | | |
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